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Contains Contents

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THE EFFECT OF SOCIAL GROUPINGS UPON THE LANGUAGE OF PRESCHOOL CHILDREN[1]

RUTH M. WILLIAMS AND MARION L. MATTSON

Children's language development has been studied from many angles but there has been little work done on the important factor of the relationship between children's verbal responses and the number of child and adult companions. Since language is primarily a response to a social situation, is intended to convey meaning to some other person, the presence of other people in the environment would seem to have an influence upon the quantity and maturity of language activity.

This study is an attempt to determine what is the effect of increasing the size of the play group of nursery school children upon their language.

PREVIOUS INVESTIGATIONS

In order to study the social behavior of children which is expressed by language, various experimental methods have been worked out. Piaget (7) made an intensive study of the language of two children under ordinary home conditions where there was no attempt to control the situation. The language records of these children were classified according to different types of social and egocentric speech. McCarthy (5) recorded 50 verbal responses for each of 140 children when they were exposed to the same play materials in an experimental situation. In this study a modified form of Piaget's classification was used.

Fisher (2) analyzed stenographic records of large samples of language expression of 72 children in a natural nursery school situation. When acceptably high reliability on the Piaget classification could not be obtained, a special classification was worked out by dividing language into the four following categories: self as the subject, other person as the subject, a thing as a subject, and non-verbal language. Fisher found that the use of structurally complete sentences increased rapidly up to the beginning of the fourth year, thereafter the ratio of complete and incomplete sentences remained constant.

Studies have been made in which all-day conversations were analyzed according to parts of speech. Investigators generally agree that there is a marked decrease in the percentage of nouns and a corresponding increase in percentage of verbs during the preschool years. Verbs increase from 14 to 25 per cent; adjectives almost double; adverbs show no consistent tendency with age never exceeding 9 per cent. Pronouns gain from 10 to 20 per cent up to the age of 30 months and then remain constant. Prepositions and conjunctions appear late and do not form an important part of the child's vocabulary (6).

[1] *The study was made in partial fulfillment for the requirements of a Master's degree at Purdue University, Lafayette, Indiana. The work was directed by Dr. Mattson.*

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METHODS

Subjects

Subjects were 6 children attending the nursery school at Purdue University. The group consisted of 3 boys and 3 girls, who ranged in age at the beginning of the experiment from 43 to 46 months and with I. Q.'s from 104 to 116 on the Minnesota Preschool Scale. These children had all been in nursery school the previous year so were familiar with the environment and each other. They were accustomed to being invited into the experimental room to "play games", a procedure to which they usually looked forward with eagerness.

Recording Machine

Ten minute language records were secured by means of a Fonda Recorder[2] which transcribed upon acetate tape all verbal responses that occurred within the room. It was thus possible to obtain an accurate record of the language responses of the entire group of subjects at the same time.[3]

Experimental Set-up

An experimental play situation was set up in a small room adjoining the nursery school. This was equipped with a low table and chairs and a cabinet containing such toys as a small doll family, rubber animals and trucks, blocks, pencils and pads, toy telephone and picture books. It was felt that such a wide range of play materials would hold interest for each child. There were also pictures on the wall and a bowl of goldfish. The recorder was placed behind a screen in such a way that it could be operated by the experimenter but was not visible to the subjects.

Each child had a turn to play freely with these materials alone, alone with the experimenter, and in a group composed of one other child and the experimenter, and also in a group composed of two other children and the experimenter. As all possible combinations of children were utilized each child was in the play situation for 17 different 10 minute periods. In all, there were 47 ten minute language records, or a total of 470 minutes of language records.

ANALYSIS OF LANGUAGE RESPONSES

The language responses were transcribed on paper and arranged into sentences, a natural pause on the record indicating what constituted a sentence. The language responses were then analyzed according to the four following classifications: type of sentence, parts of speech, social usuage, and a modification of Piaget's functional analysis.

Analysis I - Type of Sentence

1. For this study, a complete sentence was defined as any sentence which has a complete meaning for the child. It may be structurally incomplete.

[2]Manufactured by the Fonda Corporation, New York City. This was an experimental design and is not in commercial production.

[3]In order to check the accuracy of the record transcribed from the acetate film the investigator, after an interval of 3 months, again transcribed all of the records of a single child in the study and found a 93 per cent agreement with her first record for that child.

2. Each sentence was classified either as a complete sentence or an incomplete sentence. At the same time, the number of words in the sentence was counted.
3. Contractions were considered as one word.
4. Dashes indicated pauses.
5. Names of people, such as John Smith, were one word.
6. Hyphenated words were one word.
7. Infinitives and participles were counted as one word.

Analysis II - Parts of Speech

The definitions for the parts of speech were taken from a standard English text book (1).

Analysis III - Social Usage

1. Parallel speech: A child talks to himself when someone else is in the room. When a child telephones to someone else outside the room, it is a parallel speech.
2. Social speech: One child talks to another, exchanging ideas, asks a question and either gets or receives an answer, etc. When a child talks on a telephone to someone in the room, it is social speech.
3. Monologue: One child talks to himself as if thinking out loud. No one else is in the room.
4. Each sentence was classified as parallel speech, social speech, or monologue.
5. Each sentence received only one classification.

Analysis IV - Piaget's Analysis

A. Socialized Speech
   1. Friendly intercourse is an exchange of thought or ideas of two or more people. It is a friendly conversation directed to someone or giving out information for the benefit of someone.
   2. Criticism includes all remarks about the behavior of a thing or person.
   3. Commands, request, and threats are all wishful words.
   4. Questions are any remarks that definitely require an answer from the hearer.
   5. Answers are all answers to real questions or commands.

B. Ego-centric Speech.
   1. Repetition is the repetition of words or syllables for the pleasure of talking; with no thought given of talking to anyone.
   2. Monologue occurs when a child talks to himself as though thinking out loud.
   3. Dual or collective monologue occurs when an outsider is associated with the action or thought of the moment, but is expected neither to hear nor to understand what is said (7).

RELIABILITY

Reliability of Scoring

To test the reliability of the scoring of the various categories into which language responses were divided, 6 persons, all members of the Nursery School staff, rated one-tenth of the records after a brief practice period. The transcribed sentences were analyzed individually by each one of the raters who followed the same directions that the experimenter had used.

The scores of the 6 judges were arranged in rank order and, by use of the Spearman rank method, each rater's score was correlated with that of every other rater.

As shown by Table 1, there was a wide range of reliability coefficients, but for the most part they were high. The categories of parallel speech under Social Usage, and adjectives and articles under Parts of Speech showed a definite need for a longer or more thorough practice period for the judges or a more rigid definition of the terms. Of the 33 medians of coefficients 27 were 1.00 and only 4 fell below +.85.

Fisher's study (2) rejected the classifications of dual monologue and monologue in Piaget's analysis because her judges were so unreliable. Median correlation of the judges of the present study range from +.90 to +1.00 which seems sufficiently high to permit the use of Piaget's intensive interpretation.

RESULTS

Tables 2 and 2-A are based on records for the ten minute periods regardless of whether or not conversation occurred. The following tables consider only the instances in which conversation took place.

In evaluating these tables it should be pointed out that percentages in column (D) were somewhat lowered because two of the children did not talk at all during 4 of 20 ten minute periods. In all other periods in this study, every child spoke at least a few words.

Analysis I - Type of Sentences

From an examination of Table 2 one can see that the largest average number of sentences, 30.53, occurred when two children were in the experimental room with the observer. We find that the highest average number of words in a sentence, 4.18, also occurred when two children and an observer were together. The average number of words per sentence remains almost constant as the size of the group is increased and is in substantial agreement with other studies. Smith (9) found an average of four words per sentence at the age of 3½ years; while Strang (10) reports an average of three and seven-tenths words at the same age.

The greatest amount of talking occurred when there were one or two children in the room at the same time. While the differences are not great, the analysis reveals a slight tendency for the group of two subjects and an adult to be more talkative. In this combination it is interesting to note that every child talked some; whereas in the largest group, 36 per cent of the time respectively, a child did not talk at all.

TABLE 1

MEDIAN AND RANGE OF RELIABILITY COEFFICIENTS OF THE SIX JUDGES ON EACH TYPE OF CLASSIFICATION

Classification	Median	Range
Type of Sentence		
Complete sentence	+ 1.00	+ 1.00 to + 1.00
Incomplete sentence	+ .85	+ .85 to + 1.00
Number of Words in a Sentence		
One word	+ 1.00	+ 1.00 to + 1.00
Two words	+ 1.00	+ 1.00 to + 1.00
Three words	+ 1.00	+ .10 to + 1.00
Four words	+ 1.00	+ 1.00 to + 1.00
Five words	+ 1.00	+ 1.00 to + 1.00
Six words	+ 1.00	+ 1.00 to + 1.00
Seven words	+ .60	+ .60 to + 1.00
Eight words	+ 1.00	+ 1.00 to + 1.00
Nine words	+ 1.00	+ 1.00 to + 1.00
Twenty-five words	+ 1.00	+ 1.00 to + 1.00
Parts of Speech		
Noun	+ 1.00	+ 1.00 to + 1.00
Pronoun	+ 1.00	+ 1.00 to + 1.00
Verb	+ 1.00	+ .90 to + 1.00
Adverb	+ 1.00	+ 1.00 to + 1.00
Adjective	+ .60	+ .10 to + 1.00
Conjunction	+ 1.00	+ 1.00 to + 1.00
Article	+ .40	+ .40 to + 1.00
Interjection	+ 1.00	+ .60 to + 1.00
Preposition	+ .90	+ .90 to + 1.00
Play word	+ 1.00	+ 1.00 to + 1.00
Social Usage		
Monologue	+ 1.00	+ 1.00 to + 1.00
Parallel speech	+ .60	+ .60 to + 1.00
Social speech	+ 1.00	+ 1.00 to + 1.00
Piaget's Interpretation		
Friendly intercourse	+ 1.00	+ .90 to + 1.00
Criticism	+ 1.00	+ 1.00 to + 1.00
Command	+ 1.00	+ 1.00 to + 1.00
Questions	+ 1.00	+ 1.00 to + 1.00
Answers	+ 1.00	+ .60 to + 1.00
Repetition	+ 1.00	+ 1.00 to + 1.00
Monologue	+ 1.00	+ .90 to + 1.00
Dual Monologue	+ 1.00	+ 1.00 to + 1.00

TABLE 2

TYPE OF SENTENCE

(A)	Alone with Experimenter (B)	Two Children and Experimenter (C)	Three Children and Experimenter (D)
Total number of children participating	6	6	6
Number of situations	6	15	20
Average number of words for the ten minute period per child	126	127	116
Average number of words per sentence	4.07	4.18	3.99
Average number of complete sentences	28.66	29.87	22.78
Average number of incomplete sentences	.16	.35	.21
Average total number of sentences	28.82	30.53	22.99

TABLE 2A

STATISTICAL SIGNIFICANCE OF ANALYSIS OF TYPE OF SENTENCE

	B-C		B-D		C-D	
	t	per cent	t	per cent	t	per cent
Average No. of words for the ten minute period per child	4.01	1	3.35	2	2.54	5
Average No. of words per Sentence	.130	90-100	.115	90-100	.126	90-100
Average No. of Complete Sentences	3.34	2	3.56	1-2	2.43	5-10
Average No. of Incomplete Sentences	.128	90-100	.131	90-100	.131	90-100
Average Total No. of Sentences	3.32	2	3.34	2	2.00	10

The average number of words per child for the ten minute period was almost constant 116, 126, and 127, in the three situations.

In an effort to determine whether the differences of the means of the various sized groups were significant, the "t" statistics (4) were calculated for each difference. Results as large as those that appear in the accompanying tables occur by chance only the percentage of the time indicated in the various columns. From observing Table 2A, we notice that the "t" scores under "average number of words per sentence" and "average number of incomplete sentences" are not reliable but that the results of the other categories are highly reliable.

Analysis II - Parts of Speech

This study agrees with previous studies in the frequency of the different parts of speech used. Nouns and pronouns when added together were most frequent, verbs came next, adverbs and adjectives followed. The other parts of speech were of minor importance in the vocabulary of this group of children 3½ years old. Percentages of the various parts of speech remained relatively constant regardless of the size of the group except in the case of adjectives which decreased and adverbs which increased as the size of the group increased. Apparently children of this age describe action more than things as the size of the group increases. The averages for the remaining parts of speech seem to be quite consistent for the various sized groups. Play words such as "gee, gee", "boobe", and "pooly wooly" tend to decrease in frequency as the size increased.

Low percentages based upon "t" scores in Table 3A indicate that in general, differences found between parts of speech in different social groups are true differences not due to chance. Twenty-four of the 30 differences would occur by chance from one to ten times in a hundred.

TABLE 3

PARTS OF SPEECH

(A)	Alone with Experimenter 6 situations (B)	Two Children and Experimenter 15 Situations (C)	Three Children and Experimenter 20 Situations (D)
		Percentages	
Pronouns	20.78	20.26	18.99
Nouns	8.97	9.92	13.99
Total of Nouns and Pronouns	29.75	30.18	32.98
Verbs	28.73	27.93	27.23
Adverbs	10.02	17.05	17.52
Adjectives	19.00	10.31	9.53
Prepositions	2.10	4.39	3.81
Articles	4.67	4.99	4.52
Interjections	3.85	2.37	2.90
Conjunctions	2.38	1.26	1.02
Play words	.23	2.38	1.30

TABLE 3A

STATISTICAL SIGNIFICANCE OF PERCENTAGE ON PARTS OF SPEECH

	B-C		B-D		C-D	
	t	per cent	t	per cent	t	per cent
Pronouns	2.34	5-10	2.22	5-10	2.19	5-10
Nouns	2.41	5-10	2.16	5-10	2.50	5-10
Verbs	1.20	20-30	1.10	30-40	2.32	5-10
Adverbs	4.04	1	4.03	1	2.99	2- 5
Adjectives	4.04	1	4.00	1	2.45	5-10
Prepositions	4.01	1	3.96	1- 2	4.03	1
Articles	1.10	30-40	2.34	5-10	4.00	1
Interjections	2.30	5-10	.99	30-40	.10	90-100
Conjunctions	1.27	20-30	1.55	10-20	1.03	30-40
Play words	1.14	30	1.63	10-20	2.32	5-10

These are pronouns, nouns, adverbs, adjectives and all but one of the prepositions, articles. Verbs, interjections, conjunctions and play words are relatively less stable. Only the last combination of interjections shows marked unreliability.

Analysis III - Social Usage

The greatest amount of social talking, 78.17 per cent, occurred when two children were in the experimental room with the observer.

This study indicates that children 3½ years old talk more and are more sociable in small groups. From general observation we know that there is a tendency for large groups to baffle a young child.

Parallel speech occurred when a child talked to himself when someone else was in the room. The most favorable situation for this type of speech was found to be when one child was in the experimental room with an uninterested observer. Larger groups seemed to inhibit parallel speech and to stimulate social speech. Parallel speech often occurred when a child was putting the puzzle together and talking to himself about it without expecting or getting any verbal response from other children in the room who were playing with other materials.

The figures on Table 4A show that differences obtained on Social Speech and "Parallel Speech" are highly reliable. This is true of only two of the three combinations on Monologue.

Analysis IV - Piaget's Functional Analysis

Table 5 shows that children engaged in more friendly conversation as the size of the group increased. There was less criticism and commanding when a child was alone with an observer than in any other social situation. This situation in which the adult was present was not a natural one, because as was pointed out before, the adult was an observer only and discouraged social approaches. When other children were added to the group, there was more criticism, commanding, and answering questions and commands.

It is also interesting to note that four of the categories according

TABLE 4

SOCIAL USAGE

	One Child with Experimenter 6 Situations (B)	Two Children with Experimenter 15 Situations (C)	Three Children with Experimenter 20 Situations (D)
		Percentage	
Sentences that were Monologue	0	0	0
Sentences that were Parallel Speech	39.87	21.83	33.39
Sentences that were Social Speech	60.13	78.17	66.61

TABLE 4A

STATISTICAL SIGNIFICANCE OF PERCENTAGES ON SOCIAL USAGE

	B-C		B-D		C-D	
	t	per cent	t	per cent	t	per cent
Monologue	2.45	2-5	2.30	2-5	.09	90-100
Parallel Speech	3.98	1-2	4.03	1	3.75	1-2
Social Speech	3.76	1-2	3.32	2	3.65	1-2

to Piaget's functional analysis; "friendly intercourse", questions, monologue, and dual monologue, have the highest averages regardless of the size of the group.

All the comparisons on percentages of Piaget's functional analysis are fairly reliable.

On the whole, the analysis of reliability by the method of "t" statistics, shows the results of the study to be sufficiently stable; so one would expect to get comparable results by repeating this study with other similar groups of children.

Situations When a Child Was Alone

Because every child reacted as if he were in a social situation when he was alone with the observer, it was decided to try each child in the playroom entirely alone; with the observer hidden behind an observation screen.

In this situation only one of the 6 children used verbal language. She talked continuously while she was playing using a total of 60 sentences. The range of average number of words per sentence for the three social groups, 3.99, 4.07, 4.18, dropped to 2.75 when the child was entirely alone.

TABLE 5

PIAGET'S FUNCTIONAL ANALYSIS

	Alone with Experimenter 6 Situations (B)	Two Children with Experimenter 15 Situations (C)	Three Children with Experimenter 20 Situations (D)
		Percentage	
Percent of Sentences which were: Friendly Intercourse	13.49	22.25	24.09
Criticism	.52	1.71	2.97
Command	0	7.05	7.84
Questions	27.68	16.96	16.67
Answers	0	5.30	6.10
Repetition	.52	5.37	3.47
Monologue	37.55	19.18	27.49
Dual Monologue	20.04	18.86	11.31

TABLE 5A

STATISTICAL SIGNIFICANCE OF PERCENTAGES ON PIAGET'S FUNCTIONAL ANALYSIS

	B-C		B-D		C-D	
	t	per cent	t	per cent	t	per cent
Friendly intercourse	4.00	1	4.01	1	2.23	5-10
Criticism	1.06	30-40	4.03	1	4.00	1
Command	4.03	1	3.30	2- 5	3.26	2- 5
Questions	2.33	5-10	2.33	5-10	4.03	1
Answers	4.02	1	4.03	1	1.32	20-30
Repetition	2.32	5-10	4.02	1	4.02	1
Monologue	4.00	1	4.03	1	4.10	1
Dual Monologue	2.76	2-5	1.92	10-20	3.56	1- 2

The percentage of various parts of speech which the child used in the situation when she was entirely alone is substantially the same as for children in social groupings as is shown in Table 6.

According to Piaget's analysis 88 per cent of the sentences of this child were repetition. She repeated "Bunny rabbit" many times as she played with the rabbit puzzle. In this case language was an accompaniment to play activity rather than a means of communication. Twelve per cent of the sentences were classified as monologue. Examples of this type of speech are: "It is hot in here", "I don't need this", and "This is going to be a big building".

There was no criticism or commanding when the child was alone, a fact to be expected since criticism and commands are usually directed towards other people and are functions of the social group.

TABLE 6

PERCENTAGE OF PARTS OF SPEECH IN THE SITUATION WHEN THE CHILD WAS ENTIRELY ALONE

	Percentage
Pronouns	3.20
Nouns	32.09
Total of Nouns and Pronouns	35.29
Verbs	20.85
Adverbs	5.34
Adjectives	31.55
Prepositions	1.60
Articles	1.60
Interjections	0
Conjunctions	1.06
Play Words	2.62

SUMMARY AND CONCLUSIONS

An attempt has been made in this experiment to investigate the changes in various phases of the preschool child's language, when the size of the group is increased. Six children of the Purdue Nursery School, whose chronological ages ranged from 3 years, 5 months to 3 years, 10 months, served as subjects.

The children were invited into a controlled play situation, in different sized groups, and records were made of the language that occurred during ten minute periods. The data were analyzed under four classifications: type of sentence, parts of speech, social usage, and Piaget's functional analysis. The differences indicated are for the most part statistically significant.

Analysis of the data regarding type of sentence leads to the following conclusions:

1. Most talking occurs when two children are in the play situation with the experimenter.

2. The average number of words per sentence remains practically constant for the three social situations and agrees substantially with other investigations. For the 3½ year-old child it is about 4.06.

3. Only one of the 6 children talked when alone in the play situation. Speech was largely repetition, an accompaniment to activity rather than a means of communication.

When data were analyzed according to parts of speech, it was found that:

1. Nouns and noun substitutes are most used.
2. Verbs are second in frequency.
3. Adjectives and adverbs are third in frequency.
4. Other parts of speech form a minor part of the child's vocabulary and remain relatively constant as the size of the group changes.
5. Children describe action more than things as the size of the group increases.

The following trends are revealed from the analysis of social usages:

1. When the child is alone, the total speech is monologue with no social or parallel speech.
2. Social speech occurs most often when two children and an adult are in the room together.
3. The most favorable situation for parallel speech occurs when one child and an observer are in the experimental room.

When the data are analyzed according to Piaget's classification, several definite trends are noticed:

1. As the group becomes larger the language used by the children becomes more sociable and less egocentric.
2. There is slightly more criticism as the size of the group increases.
3. There are no commands when children are alone or with an adult, and the number of commands is relatively constant when other children are added to the group.
4. There are no answers to questions or commands when children are alone or with an adult; answers and questions are more frequent for groups and are relatively constant when other children are added to the group.
5. There are more questions when one child is with an adult than in any other social situation studied.
6. The amount of repetition is high in the single child situation but decreases when other children are added to the group.
7. There is a considerable amount of monologue and dual monologue even when several children are in a group together.

Of the social groups investigated, this study points out that the combination of two children and an adult results in more talking, more words per sentence, and more "friendly intercourse" than any other size of group which was included in this study. Whether this would be true of other ages or larger groups, is a question for further investigation. Because social growth is of prime importance in the life of the child, every opportunity for such experiences should be provided. From the findings of this study, we see that small social groups are the most favorable for verbal language of 3½ year-old children.

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A COMPARISON OF NEGRO AND WHITE PRESCHOOL CHILDREN ON A VOCABULARY TEST AND AN EYE-HAND COORDINATION TEST

JOSEPH E. MOORE[1]

Are negro children superior to white children in speed of reaction? Klineberg (1) contends that the difference favoring white subjects on most tests is due to environmental training. Recent investigators in attempting to ascertain whether the differences are due primarily to environmental influences employed young children rather than children who are older, and therefore more likely to show the results of training Thus far the data (2), (3), (4) reveal no statistically reliable difference between negro and white children when activities such as walking a line, threading a needle, stylus tapping, and placing marbles in holes one at a time have been employed.

The present investigation employs two measures: first, that of language, which was thought particularly susceptible to environmental influences and stimulation and second, an eye-hand coordination test which would probably parallel more closely differences due to growth and maturation and would not be so readily changed by environmental stimuli. It was hoped that the results of this investigation would throw a little more light on differences which may or may not be due to innate or maturational factors.

SUBJECTS

The subjects were drawn from private, public, and governmental (W. P.A.) nursery schools and kindergartens of Tennessee and Kentucky. The 78 negro subjects came from four different schools. The 82 white subjects came from five schools. The background and economic condition of the members of the two different groups ranged all the way from the very poor to the well-to-do.

PROCEDURE

Two individual tests were administered to each negro and to each white child used in the study. These tests were the Van Alstyne Picture Vocabulary Test for Preschool Children and the Preschool Form of the Moore Eye-Hand Coördination Test. The Van Alstyne test consists of 45 cards on each of which are four pictures of objects or experiences common to small children. A child is asked to "show" the experimenter a certain object on each card. No vocalizing is necessary, the child is merely asked to "point to" or "show" the desired object. The score is the number of cards on which the test object is correctly identified. The Moore Eye-Hand Coordination test requires a child to place 16 marbles, one at a time, in separate holes in a board. The marbles are five-eighth of an inch in diameter. The child's score is the total number of seconds necessary to repeat the test three times. A short rest period is permitted between each of the three trials. Care was taken to see that each child was seated in such a way that his arms were

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not forced into an awkward position, either too high or too low, as he took the test. The observations made during the practice trial afforded a means of adjusting table height or chair size to the subject. The experimenters took pains to motivate each child after each trial, no matter what the performance was, by saying, "That was good," or "You did that well."

The majority of the tests were administered by the investigator, others were given by a graduate student in psychology with experience in dealing with preschool children. Each child was taken individually to a quiet room and tested. The eye-hand coordination test was given first to each child because of the ease of motivating the subject. The vocabulary test was given the following day. All testing was done in the morning hours between eight and eleven o'clock. The room in which the testing was done was quiet and enabled the child to be tested under the most favorable conditions. The children in both groups appeared to respond unusually well to both tests.

RESULTS

The results from the Van Alstyne Vocabulary Test indicate that the white children were superior to the negro children at all age levels compared, with the exception of the 42-47 month group whose median score excelled that of the white group by one word. Figure 1 gives a comparison of the number of pictures identified correctly by children in the two racial groups at different age levels.

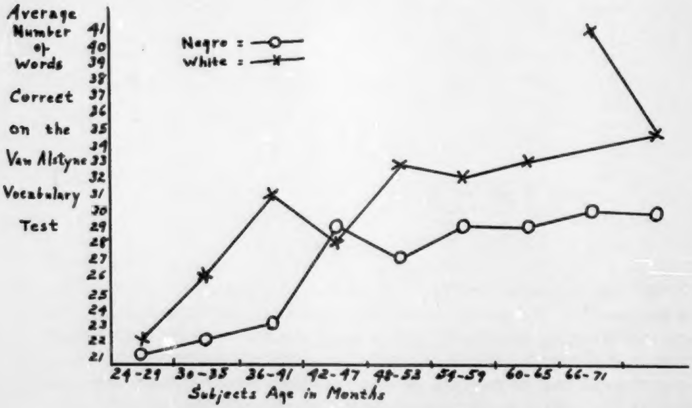

Figure 1

The data represented in Figure 1 indicate that vocabulary knowledge, as represented on the Van Alstyne Test, increases with age for both the negro and white group. The increase appears to be slower for the negro group and the curve of growth appears to flatten out a little more rapidly at the upper age groups, those from 54 to 72 months. It may be that white children have an earlier advantage of picture books, blocks,

and perhaps more attention from their parents which might stimulate a superior vocabulary development. The plateau effect seen in the curve for negro children may be due to the fact that the choice of experiences used by Van Alstyne parallels those of white children more closely than would be the case for the Negroes. The two groups start only one word apart in the 24-29 month group. If the data were smoothed they would show a rather consistent trend for the white children to excel the negro children in vocabulary development in this investigation. The superiority of the white children over the negro children on the eye-hand coordination test is neither consistent nor marked at any level. Negro children were superior to white children between the ages of 24 to 35 months of age. A detailed comparison of the achievement of both white and negro children can be seen in Figure 2.

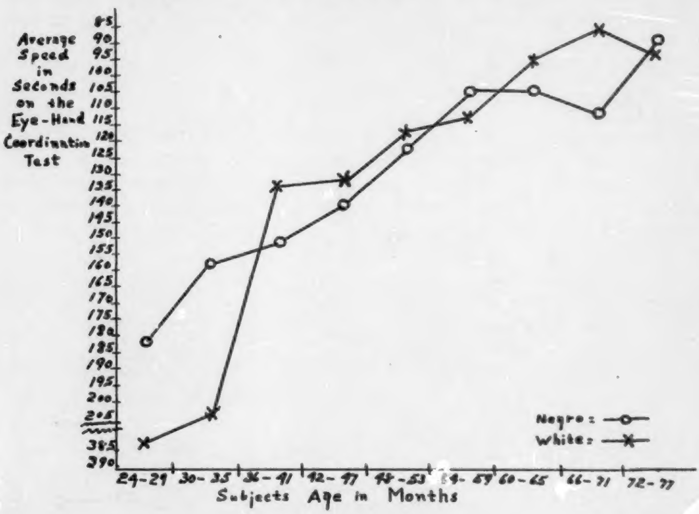

Figure 2

The similarity of the two curves representing speed of reaction for the negro and white groups stand out more than the differences. The negro children in the two youngest age groups, 24 to 35 months, are markedly superior to the white children. This superiority at the two youngest ages may or may not be due to sampling; in either case the trend of the performance is such as to warrant further investigation.

The detailed record for each age group is presented in Table 1 for the Van Alstyne Vocabulary Test and in Table 2 for the speed scores on the Eye-Hand Coordination Test.

The fact that white children in this study are more variable on the vocabulary test than are the Negroes, can be seen by consulting the average deviations in Table 1. In six of the nine age groups compared the performance on Van Alstyne Vocabulary test is more variable for the white

TABLE 1

AVERAGE NUMBER OF WORDS CORRECTLY IDENTIFIED BY 78 NEGRO AND 82 WHITE SUBJECTS ON THE VAN ALSTYNE VOCABULARY TEST BY AGE GROUPS

Months	24-29	30-35	36-41	42-47	48-53	54-59	60-65	66-71	72-77
N	3	8	7	15	20	11	8	7	3
White Mdn.	24	24	32	25	34	35	35	41	37
Mean	22.3	26	30.6	27.9	33.1	32.3	32.8	41	35
Av.D.	2.89	9.3	3.31	7.18	5.75	6.25	4.62	1.7	3.0
Voc. N	5	6	9	11	6	17	16	4	4
Negro Mdn.	21	22	22	26	28	31	29	29	30
Mean	21.2	22.2	22.6	28.5	26.6	28.8	29.1	28.8	30
Av.D.	3.0	3.2	3.9	4.1	4.5	5.03	3.3	5.3	2.5

TABLE 2

THE AVERAGE SPEED IN SECONDS FOR 78 NEGRO AND 82 WHITE SUBJECTS ON THE MOORE EYE-HAND COORDINATION TEST

Months		24-29	30-35	36-41	42-47	48-53	54-59	60-65	66-71	72-77
White	N	3	8	7	15	20	11	8	7	3
Eye Hand	Mdn.	318	182	137	133	119	106	89	88	92
Coordination	Mean	388	206	134.6	133.8	119	114	95.1	86.4	93
	Av.D.	49.0	51.0	10.0	17.3	17.8	18.7	13.9	5.3	6.7
	N	5	6	9	11	6	17	16	4	4
Negro	Mdn.	180	150	153	132	116	98	103	98	91
	Mean	182.6	158	153	140.6	122.5	106.6	104.7	112	88.5
	Av.D.	27.3	24.9	22.3	27.0	23.1	14.4	10.4	14.0	4.5

than for the negro subjects. The size of the average deviation indicating the greater variability of the white children is worth noting for the ratio on the largest to the smallest is about five to one. On the other hand, the negro children have a very small variation, only about half that of the white or two to one when the largest variation is compared to the smallest. The greater variability of the white group may tend to support the idea of a richer, more varied type of background for this group.

The results on the Eye-Hand Coordination Test shown in Table 2 indicate that white children are more variable than negro children on

five of the nine comparisons. The range of the average deviations for white children is from 5 to 50 seconds, whereas that for the Negroes is only 5 to 27 seconds.

SUMMARY

1. The white children used in this study are superior to the negro children in identifying pictures on the Van Alstyne Preschool Vocabulary Test in eight out of the nine age groups compared. The growth curves for word knowledge were very similar in shape and trend. The vocabulary curve for negro children appeared to flatten out markedly at the upper age groups.

2. The results on the Preschool Form of the Moore Eye-Hand Coordination Test showed the white group superior on five out of the nine age groups. The superiority of the white group was not as marked on the eye-hand coordination as on vocabulary knowledge. The similarity of the speed curves for both negro and white children was more marked than the difference.

3. The negro subjects were less variable on both tests. On six out of the nine comparisons on the vocabulary test and five out of nine comparisons on the Eye-Hand Coordination Test the negro children appeared more homogeneous in their performance than did the white children.

4. The marked superiority of the negro children over the white children at the two youngest age groups needs further investigation to determine if the difference is due to sampling or to other factors not yet investigated, or not touched in this investigation.

5. The data in this study appear to favor the position that tests were employed which reflect cultural advantages, such as may be the case with the Van Alstyne Test, and which show a greater difference in favor of the white children than would be the case with tests less influenced by specific environmental stimulation, such as the Eye-Hand Coordination Test.

Comments

The writer regrets that a more accurate check on environmental factors such as the possession of balls, blocks, books, toys, and especially marbles was not made. It would be desirable for a more comprehensive study to be made in which the experimenter would visit in the children's homes and check with parents as to what particular blocks, toys, et cetera were and had been used by each child.

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CARDIOMETRIC STUDIES ON CHILDREN

IV. A-V NODAL ESCAPE AND NODAL RHYTHM IN AN OTHERWISE NORMAL SUBJECT[1]

WILLIAM E. POEL AND CARROLL E. PALMER

During a medical survey of more than 2400 apparently normal high school students in New York City, one pupil was found whose electrocardiogram showed A-V nodal rhythm and periods of A-V nodal escape in which the P-R interval varied from 0.04 sec. to 0.16 sec. Willingness on the part of the student to cooperate in additional experiments led to the electrocardiographic observations reported in this communication. The prevalence of nodal rhythm totaled two cases in the 2400 students examined. In addition to the case described, a 16 year-old Negro was found whose electrocardiogram showed nodal rhythm with both forward and retrograde conduction. The longest P-R interval recorded was 0.13 sec., the longest R-P interval recorded was 0.20 sec. Except for the electrocardiographic findings the boy's survey examinations showed him to be normal. Further studies could not be made at the conclusion of the survey because the boy was discharged from school and could not be located.

Physiologic Consideration of Dual Pacemakers in the Heart

"In the normal heart several centers of rhythm formation are potentially active, but the center which generates an impulse most rapidly sets the pace of the heart" (4). The pacemaker is normally the sino-auricular node, and the heart beating in response to impulses from the sinus node is said to possess "sinus rhythm". The normal sequence of the cardiac cycle exists, provided that forward conduction between the sino-auricular and auriculo-ventricular node is unimpaired and the auricular center is the more rapid. Should the rate of the A-V node become equal to that of the auricular center, sinus rhythm will be maintained only if the discharge of the sinus impulse precedes that of the A-V node by an interval at least equivalent to the normal auricle-to-ventricle conduction time for the individual. If the sinus impulse precedes that of the A-V node by an interval less than that necessary for the sinus stimulus to reach the A-V node, the auricles and ventricles will beat independently, in response to their own centers, and periods of auriculo-ventricular nodal escape will be demonstrated electrocardiographically by an inconstant P-R interval which, in an individual with unimpaired forward conduction, does not exceed his normal P-R time. However, if the rate of the A-V node should exceed that of the sinus node, or if the stimulus from the lower center should precede that from the auricle, the A-V impulse will supersede the slower auricular stimuli, and the entire heart, both auricles and ventricles, will function in response to the A-V node. The electrocardiogram under such conditions is that of auriculo-ventricular nodal rhythm.

In the case reported, the operator could cause, at will, transitions from sinus rhythm to either A-V nodal escape or nodal rhythm, and trans-

[1] *From the Division of Public Health Methods, National Institute of Health, U. S. Public Health Service.*

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itions from the latter two to the former through devices such as psychic stimulation, altered respiration, changes in body position, rest, or physical exertion, as well as through certain drugs, namely, atropine and epinephrine.

History. The subject, a 16 year-old white girl, was first seen in New York City in December, 1939, as a participant in a medical survey of high school students. Save for a younger brother who had been a rachitic baby, the girl's family medical history was negative. Her birth had been normal, and as a child she had had good health except that she had measles at two years of age, and whooping cough at eight. Her medical history for the twelve months prior to the survey revealed only a cold that lasted five days, approximately a month before first examination. She was a senior in high school and had always done well in her studies.

Examination.[2] The girl's general appearance was normal, the body build intermediate, and her color good. An eye, ear, nose and throat examination was negative except for moderately enlarged tonsils. There was no palpable enlargement of the thyroid or lymph nodes. The blood pressure was recorded as 130/80, and the heart rate as 89. No systolic or diastolic murmurs were heard. The apical impulse was felt 7 cm. from the mid-sternal line in the fourth intercostal space.

The findings of all laboratory examinations, except the electrocardiographic and stethographic procedures, were normal. The Kline exclusion and diagnostic tests, and the Kolmer complement fixation test were all negative. There was no significant difference between the chronological age of the subject and X-ray assessment of her skeletal age. The results of urinalysis, as well as of hematological, and blood chemistry examinations were all within normal limits. The arm-to-tongue circulation time, as determined by using decholin, was 14.6 sec. The basal metabolic rate was +3 per cent. Anterior-posterior, oblique, and lateral chest plates showed no discernible cardiac or pulmonary deviations from the normal. Roentgenographic visualization of the esophagus as delineated by barium revealed no signs of growths or masses near it in the neck or chest.

The only unusual findings were those in the electrocardiogram which disclosed nodal rhythm in the standard leads, an inconstant P-R interval of 0.15 sec. or less in Lead IV_{CR} and a tendency toward right axis deviation (Figure 1).[3] A diagnosis of nodal rhythm was made on that basis, and the subject was advised that further heart tracings would be desirable.

Electrocardiographic and Stethographic Examination. Simultaneous electrocardiographic and stethographic observations were made at a number of intervals between December 1939 and August 1941. Since some of the experimental procedures were repeated at successive periods, whereas others required more than one session for completion, they are presented here according to the several techniques employed, but not necessarily in chronological sequence. Only the electrocardiograms will be con-

[2]The authors are grateful to Acting Assistant Surgeon Frank Liberson, Acting Assistant Surgeon Isaac Apperman, and Assistant Surgeon (R) Henry I. Russek, all officers of the U. S. Marine Hospital, Stapleton, N. Y., for physical and laboratory examinations of the subject.

[3]Figures are placed at the end of the article.

sidered in this report. Unless otherwise specified, the electrocardiograms reproduced here were made under normal breathing conditions.

Production of Changes of Pacemaker

1. Psychic stimulation

(a) The subject had never been electrocardiographed prior to the survey. The first examination and the two following checkups, in which tracings were made with the subject sitting, all yielded graphs of nodal rhythm with spontaneously occurring periods of A-V nodal escape and sinus rhythm. Subsequent tracings in the same position, by the same operator, and under the same conditions, showed normal sinus rhythm. (Compare Figure 1 with Figure 2.)

(b) A control record taken on May 29, 1941, in surroundings familiar to the subject, shows normal sinus rhythm, with no recorded instance of nodal escape or a shortened P-R interval. (Figure 2.) A comparison tracing, taken at a Marine Hospital two days later, in the presence of a strange physician shows frequent spontaneous transitions from sinus to nodal control of the heart beat. (Figure 3-A.) A repetition of the same procedure at a later date, with the same doctor in attendance, produced graphs of regular sinus rhythm, with no variations in length of the P-R intervals. (Figure 4-A.) (Compare Figure 2.)

2. Body Position and Physical Activity

(a) Electrodes were applied to the subject, and she rested supine for 10 minutes. A tracing at the end of the 10 minutes shows regular sinus rhythm, constant P-R intervals of 0.16 sec. duration, and a heart rate of 71. (Figure 5 A.)

(b) The subject sat up, and a record was taken 3 minutes later. Regular sinus rhythm and the length of the P-R intervals were not affected by the change to a sitting position, but the heart rate had increased to 80. (Figure 5 B.)

(c) The girl then arose and stood "At ease". A tracing taken 3 minutes later portrays alternating transitions of S-A and A-V nodal control of the cardiac mechanism. The heart rate had increased to 87. (Figure 5 C.)

(d) Moderately strenuous exercise followed, in which the girl hopped on one foot until she felt tired. A record immediately after exercise shows the reestablishment of regular sinus rhythm at a heart rate of 118. The P-R intervals are again constant, but with a duration of 0.12 sec. (Figure 5 D.)[4]

(e) Further tracings were taken at 1½, 3, and 6 minutes after exercise, while the subject sat in a chair and recovered from her exertion. The tracings 1½ minutes after exercise (Figure 5 E) indicate nodal rhythm with superposition of the P wave and QRS complex. The rate is 90. After 3 minutes of rest, the record indicates the resumption of alternate variations of S-A and A-V

[4] *Vide infra p. 265.*

control of the heart beat, at a heart rate of 85. (Figure 5 F.) The tracing taken 6 minutes after exercise is practically identical with both tracings E and C above.

3. Respiration

Tracings were taken to demonstrate the effects of, 1) normal respiration; 2) regular respiration with deeply exaggerated inspirations and exhalations; 3) interrupted respiration, in which breathing was suspended for intervals of 15 to 30 seconds immediately after a deep forced inspiration; 4) interrupted respiration, in which breathing was suspended for 10 to 20 seconds immediately after a forceful exhalation; and 5) interrupted respiration immediately after a deep inspiration, following the establishment of rapid sinus rhythm by a moderately strenuous period of exercise.

The following are apparent in the tracings obtained:

(a) Continuous normal respiration does not by itself change the pattern of heart control established by preceding physical activity. (Figure 6 A.)

(b) Interrupted respiration, with breathing stopped after a deep inspiration, invariably produces the abrupt appearance either of nodal rhythm, P-R interval variations, or a combination of the two. The sequence lasts for the duration of suspended breathing and is usually accompanied by slowing of the heart rate. (Figure 6 B.)

(c) Suspended respiration, with breathing stopped after a forced exhalation, invariably establishes sinus rhythm for as long as breathing is stopped. (Figure 6 C.)

(d) Regular respiration, with deeply exaggerated inspiration and exhalation produces cyclic variations of sinus and nodal rhythm. Sinus rhythm is seen during the expiratory portion of the breathing cycle, and A-V nodal rhythm or escape is seen to be associated with the inspiratory peaks. (Figure 6 D.)

(e) Even after exercise has established a sinus tachycardia, at a rate of from 115 to 120, a deep sustained breath precipitates the appearance of an A-V nodal rhythm or escape which persists throughout the period of arrested breathing. (Figure 6 E.) An abrupt transition to sinus rhythm is seen in the second cycle following the resumption of regular respiration. (E_2.)

4. Medication

(a) Electrocardiograms were made before and after partial atropinization was obtained with 1/150 gr. Atrop. Sul., administered hypodermically. The control tracings before atropine show a predominance of sinus rhythm, but with intermittent appearance of A-V nodal escape or rhythm. The dosage used was sufficient to establish an unvarying A-V nodal rhythm within sixteen minutes after the drug was given. There followed an unbroken period of

A-V nodal control of the heart which lasted for fifteen minutes. The first record of a P-wave was obtained again thrity-one minutes after the injection. (Figure 3 A to F.)

(b) A similar series of tracings was made at a later date to show the effect of epinephrine on the heart. Five minims (1:1000) were injected hypodermically after control tracings had been made. Subsequent electrocardiograms were taken every two to three minutes. The changes following epinephrine are not as striking as those after atropine. They do, however, indicate that the small dose employed was sufficient to upset a definite sinus rhythm and cause intermittent periods of auriculo-ventricular nodal escape. (Figure 4 A to G.)

Discussion

"The usual case of auriculo-ventricular nodal rhythm seen clinically is due to sino-auricular nodal depression from the effect of digitalis or some other cause, generally unknown" (3). In the case presented here, however, sino-auricular nodal depression is not present; the lowest heart rate recorded was 71. (Figure 5 A.) Furthermore, the P-R interval does not exceed 0.16 sec. in any instance, eliminating auriculo-ventricular dissociation due to heart block as the cause of the P-R fluctuations. A different basis for the explanation of nodal rhythm and A-V nodal escape must, therefore, be sought in this case, Since the only essential intra-cyclic fluctuations are those of the P-R interval, it seems that two active pacemakers are present; one in the sino-auricular node controlling the auricles, the other in the auriculo-ventricular node controlling the ventricles. The assumption of two pacemakers in the heart is necessitated in view of the following;

1. All P-waves and QRS complexes are within normal limits.
2. All P-waves are upright and identical in contour and duration.

   The assumption of a single pacemaker, lying somewhere in the junctional tissue or in the auriculo-ventricular node and activating both auricles and ventricles, would imply retrograde conduction to the auricles. Records of cases with retrograde stimulus conduction show distorted or inverted P-waves (1) (2). However, none of our records displays any changes whatever in the P configuration, other than those due to, and occurring at the time of, superposition of the P-wave and QRS complex.
3. All P-waves during period of A-V nodal escape are identical with the P-waves recorded in those tracings of apparent sinus control. The site of origin of all auricular impulses is therefore constant in the S-A node.
4. The QRS complexes during periods of nodal rhythm and A-V nodal escape are identical, in contour, duration, and direction, with those recorded during periods of apparent sinus control;[5] except for those changes due to, and occurring at the time of, superposition of the P and QRS configuration.

The site of all <u>ventricular</u> impulses is therefore constant; in the A-V node.

[5] *Compare QRS complexes during sinus and nodal rhythm; Figs. 6 C and D.*

With the above as a basis, the P and QRS configurations may be interpreted as indicating the moments of activation of the auricles and ventricles by their respective nodes; and the variations in the P-R interval thus indicate variations in the time between the moments of such activation.

Theoretically, changes to and from nodal rhythm, A-V nodal escape and sinus rhythm may be explained as due to a depressed sino-auricular node, an auriculo-ventricular node having an enhanced rate of impulse formation, or to a combination of both the factors (1). The possibility of the case described being due to a depressed S-A node has already been ruled out. Furthermore, Figure 5 D shows that the sinus node is capable of normal physiologic response to strain and exercise. We are thus left with the only alternate possibility, a hyperactive A-V node.

The findings fit, in nearly all respects, the concept of a hyperactive auriculo-ventricular node. The cardiac variations produced by changes in body position and respiration tend to indicate that the rate of impulse formation in both nodes is almost identical, and that the vagal effects induced by body position and respiration inhibit the sinus node more than the A-V center. That concept is substantiated also by the effects of atropine and epinephrine. Figure 3 shows that release from vagal inhibition after atropine was greater for the A-V node than for the sinus node. Similarly, the action of epinephrine was to upset a dominant sinus rhythm and produce intermittent periods of A-V nodal escape. Hence the effect of sympathetic stimulation is likewise apparently greater on the A-V node than on the auricular center.

The effect of exercise on the heart was, in this subject, as interesting as it was unexpected. Since a change from a position of rest (lying down) to a more active one (standing), was accompanied by a shift in control of the heart beat from the auricular to the A-V center, it might have been expected that exercise would establish A-V rhythm even more strongly. The reverse was true, however, for Figures 5 D and 6 E show that exercise established a regular sinus rhythm at a rate of 115 to 125. The unstable nature of the sinus rhythm is nevertheless revealed by Figure 6 E, which shows that a forced deep inspiration, following exercise, overcame the activation of the S-A node, and allowed the A-V center to gain control of the heart beat at a rate of 118 for the time during which breathing was suspended.

SUMMARY

1. A medical survey of more than 2400 high school students revealed one pupil, otherwise apparently normal, whose electrocardiograms showed spontaneous transitions from normal sinus rhythm to periods of A-V nodal escape, and A-V nodal rhythm.

2. Nodal rhythm and periods of A-V nodal escape were recorded as they appeared spontaneously or were induced, at intervals over one and three-quarters years, during which periodic observations were possible.

3. In the case reported, the operator could elicit transitions in control of the heart beat between the S-A and A-V nodes through such devices as psychic stimulation, forced respiration, change in body position, rest, physical exertion, and certain drugs, such as atropine

and epinephrine.

4. The anomalous findings in the case presented are discussed in the light of hyperactivity of the A-V node.

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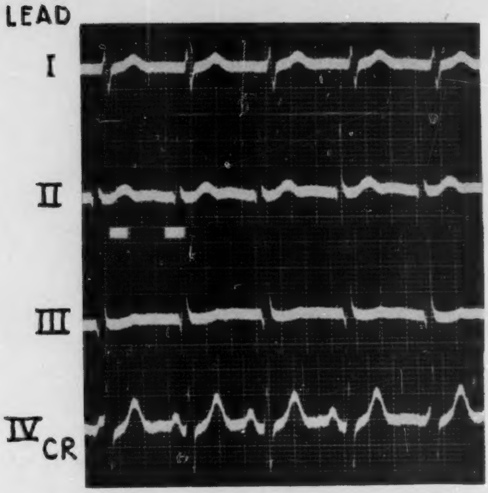

Figure 1. Routine four-lead electrocardiogram, taken in the sitting position, on December 27, 1939. Nodal rhythm is seen in the three standard leads. Lead IV_{CR} shows a period of nodal escape. The tendency toward right axis deviation in the tracing is in conformity with the 'long, hanging type' of cardiac silhouette obtained by X-ray.

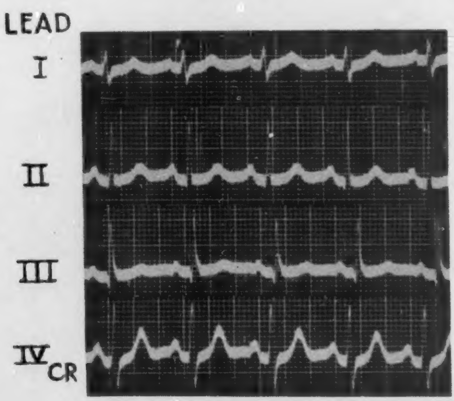

Figure 2. Subsequent electrocardiogram showing regular sinus rhythm. (Several electrocardiographic retakes in the interval between the first examination and this one had accustomed the subject to the procedure involved.)

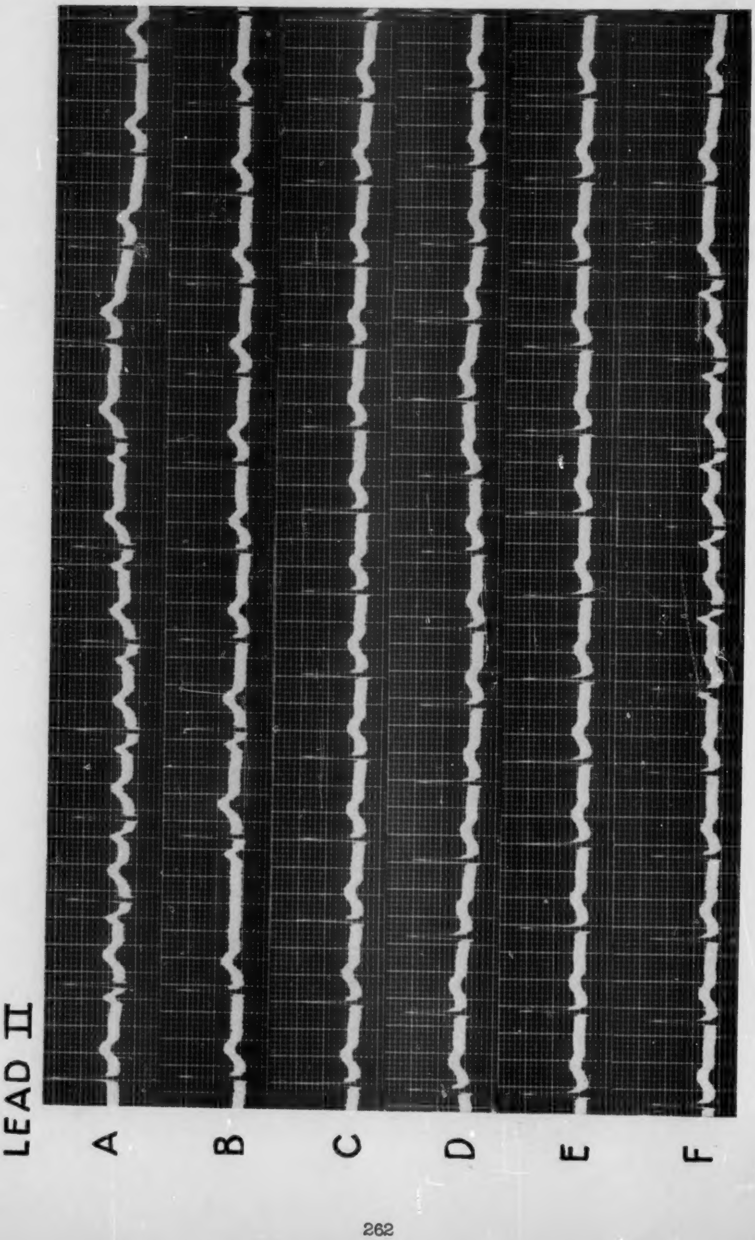
LEAD II
A
B
C
D
E
F

Figure 3. The effect of 1/150 gr. atropine administered hypodermically: All tracings were taken in the sitting position with Lead II.

A. Before atropine: Spontaneous transitions from A-V rhythm to S-A rhythm are recorded.

B. 10 mins. after a 1/150 gr. atropine sulfate hypo. The tracing is essentially unchanged.

C. 16 mins. after atropine. A nodal tachycardia is established at a rate of 100.

D. 22 mins. after atropine. The A-V nodal rate has risen to 106.

E. 28 mins. after atropine. The nodal rate has returned to 100.

F. 31 mins. after atropine. The first P-waves are recorded since their disappearance in section C above.

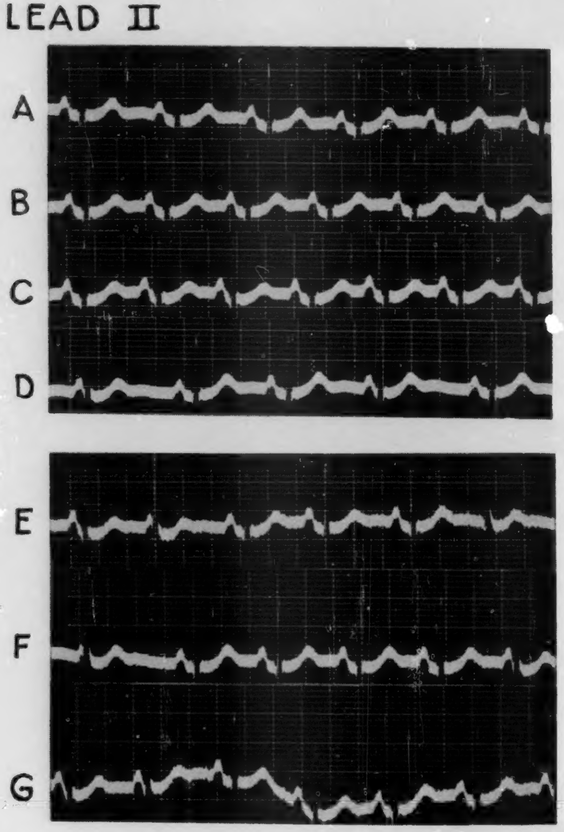

Figure 4. The effect of five minims of epinephrine administered hypodermically: All tracings are of Lead II, taken in the sitting position.

A. Before epinephrine: Regular sinus rhythm, at a rate of 90.

B. 3 mins. after epinephrine was administered hypodermically. Sinus rhythm is still present, but at a rate of 96.

C. 5 mins. after epinephrine. The second and third P-R intervals are shortened. The rate is 104.

D. 7 mins. after epinephrine. The first and fourth cycles show P-R shortening. The rate has fallen to 87.

E. 12 mins. after epinephrine. The rate is up to 106. Cycles 1, 2, and 6 show nodal escape.

F. and G. Taken 16 and 20 mins., respectively after epinephrine. Continue to show nodal escape beats.

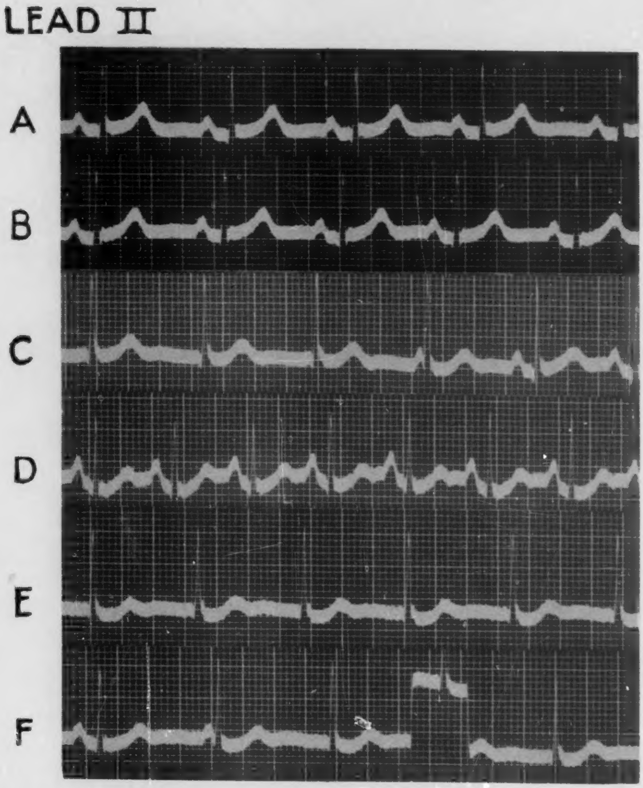

Figure 5. The effect of physical activity: All tracings are of Lead II.

A. Subject supine, after a rest period of 10 minutes: Sinus rhythm is seen; the rate is 71. P-R intervals are 0.16 sec. long.

B. Subject sitting. The rate is 80.

C. Subject standing. Regular sinus rhythm has been replaced by phasic variations from S-A to A-V rhythm.

D. Immediately after exercise: Sinus rhythm has been re-established at a rate of 118. P-R intervals are 0.12 sec. long.

E. 1.5 mins. after exercise: Nodal rhythm is present at a rate of 90.

F. 3 mins. after exercise: This tracing is essentially the same as section C above. The rate is 85.

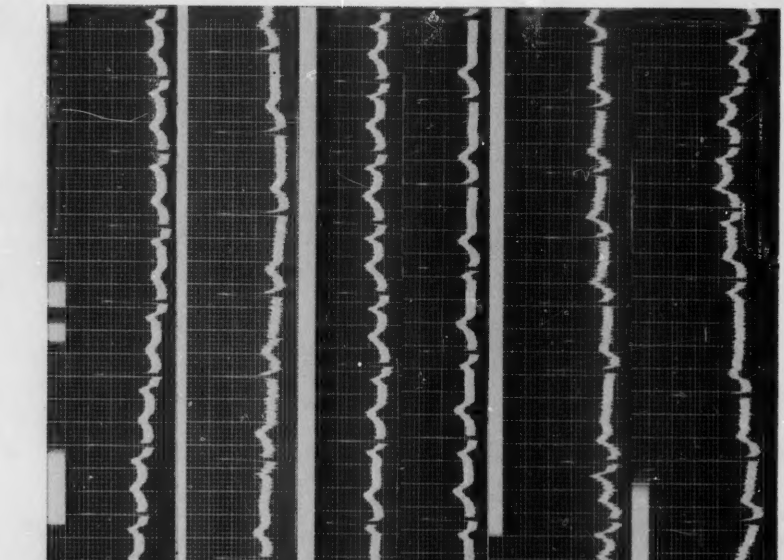
LEAD II
A
B
C
D
E1
E2

Figure 6. The effect of respiration: All tracings are of Lead II.

A. Normal respiration: One white dash indicates the peak of inspiration; two dashes indicate the beginning of exhalation.

B. Forced inspiration followed by suspended breathing: The white dash indicates the beginning of forced inspiration and the duration of suspended breathing.

C. Forced exhalation followed by suspension of breathing: The white dash indicates the beginning of exhalation and duration of suspended respiration.

D. The effect of regular but exaggerated respiration: The short period of sinus rhythm coincides with the expiratory phase of the respiratory cycle.

E_1 and E_2. The effect of a deep breath immediately after exercise; The white dash in E_1 shows when the deep breath was taken; the end of the dash in E_2 shows when normal respiration was resumed.

CARDIOMETRIC STUDIES ON CHILDREN

V. VARIABLE P-R INTERVAL AND VARIATIONS OF HEART SOUNDS AND VENTRICULAR SYSTOLE[1]

WILLIAM E. POEL AND CARROLL E. PALMER

It is known that the duration of the diastolic period preceding the auricular contraction plays a large part in determining the next stroke output, and therefore the duration of ventricular systole. However, available literature does not mention the effect on the cardiac output and ventricular systole, of variations in the time interval between auricular and ventricular contractions (that is, variations of the As-Vs or P-R interval).

Wright, in his Applied Physiology (6, p. 403) says: "On the average, auricular systole is said to contribute thirty-five per cent of the total ventricular output . . . the exact proportion depending on the time in diastole at which auricular systole occurs, the vigor of auricular systole, and the completeness with which the ventricle is already filled. ... An auricular contraction early in diastole may contribute up to sixty percent of the ventricular output, whereas at the end of a long diastole, the ventricle may already be so full that the auricle can contribute relatively little."

Simultaneously recorded electrocardiograms and stethograms, obtained in a case of A-V nodal escape and nodal rhythm presented in the preceding report of this series, offered an unusual opportunity to study the effect of variations of the As-Vs or P-R interval on the duration of ventricular systole in an organically normal heart. The stethographic data and tracings herein presented also added significantly to our understanding of the relationship between variations in the time intervals of successive auricular and ventricular contractions, and the character of the changes in the heart sounds produced by those variations.

The case reported is that of a clinically normal white girl 16 years of age, in whom transition from sinus rhythm to A-V nodal rhythm or periods of A-V nodal escape occurred spontaneously or were induced in a number of ways described.

Technique. Stethographic tracings were taken routinely at the mitral, tricuspid, aortic, and pulmonic areas. A Sanborn Stetho-Cardiette was used throughout the study. The machine is arranged to record simultaneously both the sound track and the electrocardiogram on a 6 cm. bromide-paper record. Stethograms were always run simultaneously with Lead II, at a film speed of 75 mm. per sec. The length of all desired electrocardiographic and stethographic intervals was measured in half-millimeters, dropping all smaller fractions. The measurement was multiplied by 1.333 to calculate time duration in hundredths of a second.[2] The sound tracings were taken with the standard microphone and medium sized bell supplied by the manufacturers.

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[2] *Since the film speed is 75 mm. per sec., time can be calculated by the ratio, "Length of film (in mm.): time (in hundredths of a sec.): : 75 mm.: 1 sec."*

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The usual manner of determining the duration of systole on the stethogram is to measure the interval between the beginning of the first and second heart sounds. That method could not be used in the case presented, since the variations in the initial component of the first heart sound caused by changes in the As-Vs interval of our case make this determination of ventricular systole inaccurate. Neither could the Q-wave be used as the point from which to measure the beginning of ventricular systole because the frequent superposition of the P-wave on the QRS complex obliterates the Q-wave. Consequently systolic determinations were made by measuring the distance laterally between the peak of the R-wave in the electrocardiogram, and the beginning of the second heart sound in the stethogram. Admittedly, ventricular systole begins before the recording of the peak of the R-wave. However, the difference between the beginning of systole and the R-peak is constant for all cycles in a normal subject under normal conditions, and for our purposes is not significant.[3]

P-Q Variations and the Duration of Ventricular Systole

Changes in duration of ventricular systole, which are associated with variations of the P-Q interval, are best studied in a continuous tracing made during spontaneous cardiac transitions between sinus controlled beats, nodal beats, and cycles showing auriculo-ventricular nodal escape. A tracing of that type recorded at the mitral area, is reproduced in Figure 1.[4] Because of its length the tracing is cut into three sections, the second and third of which are continuations of the first.

The measurements of the P-Q, systolic, and diastolic intervals of all cycles in the illustration are given in columns 1 to 4 of Table 1. From those measurements it can be seen that ventricular systole is definitely lengthened when preceded by an auricular contraction. For example, the P-Q interval changes from a value of 0.00 sec. in cycle 1 to 0.133 sec. in cycle 7, and that change is accompanied by a gradual increase in ventricular systole from 0.267 sec. in cycle 1 to 0.300 sec. in cycle 7. (Columns 2 and 3 of Table 1.)

However, due to variation of physiologic factors in addition to the P-Q interval, the changes in the duration of systole are not absolutely proportional to changes in the P-Q interval. A change of 0.02 sec. in the P-Q intervals of cycles 1 and 2 produces no change in the duration of ventricular systole; whereas between cycles 9 and 10, a change of 0.007 sec. in the duration of systole occurs without any change in the P-Q interval. A correlation of columns 2 and 3 of Tables 2, 3, and 5, (as well as of Table 1) shows that the relationship between the length of the P-Q interval and the duration of ventricular systole is a direct but not a quantitatively exact one. Since there is no way to stabilize all physiologic factors affecting the cardiac mechanism, a quantitatively exact relationship can not be expected.

[3] *The Q-wave, if present, begins about 2.5 mm. before the peak of the R-wave in all cycles of Lead II. By adding that interval to the length of the 'R-to-Second-Sound' systole, and subtracting the equivalent amount from the 'Second Sound-to-R-wave' diastole, more exact values for systole and diastole are obtained.*

[4] *Figures are placed at end of the article.*

TABLE 1

MEASUREMENTS FROM FIGURE 1; FOR CORRELATING VARIATIONS OF P-Q INTERVAL OF THE ELECTROCARDIOGRAM WITH CERTAIN CHANGES IN CHARACTERISTIC OF THE HEART SOUNDS AND VENTRICULAR SYSTOLE

(As the P-Q interval increases, ventricular systole is seen to increase, and the recorded first, second and third heart sounds undergo certain changes in outline, amplitude and duration. As the P-Q interval decreases, ventricular systole and the heart sounds undergo reverse changes.)

1	2	3	4	5	6	7
Cycle	P-Q interval (in sec.)a/	R-to-2nd sound systole (in sec.)a/	Duration of preceding diastole (in sec.)a/	Initial component of 1st heart sound	Amplitude of downward deflection; 2nd heart sound (in mm.)	Amplitude of 3rd heart sound (in mm.)
1	Absent	0.267	-	Taken as a basis for comparison	3.0	0.0+b/
2	0.020	0.267	0.273	Similar to that of cycle 1	2.5	0.0+
3	0.053	0.273	0.273	Outline differs from that of cycle 1	2.5	0.5 c/
4	0.080	0.280	0.243	Outline and amplitude differ from those of cycle 1	3.0	0.5 d/
5	0.127	0.293	0.243	Outline, amplitude, and duration vary from those of cycle 1	4.5	1.0 d/
6	0.127	0.293	0.233	Further changes in outline, amplitude, and duration are present	5.0	1.0 d/
7	0.133	0.300	0.243	Identical with that of cycle 6	4.5	0.5 c/
8	0.127	0.300	0.280	Of shorter duration than in cycle 6	5.0	0.5 d/
9	Absent	0.280	0.253	Similar to that of cycle 1	2.5	0.0 +
10	Absent	0.273	0.280	Similar to that of cycle 1	3.0	0.0 +
11	0.127	0.300	0.693	Duration, outline and amplitude exceed those of any other cycle	3.5	0.5
12	0.120	0.293	0.280	Similar to that of cycle 5	3.5	0.5 c/
13	0.043	0.287	0.247	Approximates that of cycle 1	2.0	0.5
14	Absent	-	0.267	Similar to that of cycle 1	Record ends	

a/ See text (p. 270) P-Q variations and the duration of ventricular systole
b/ 0.0 + indicates less than 0.5 mm.
c/ The third heart sound vibration coincides with the beginning of the P-wave of the following cycle (see text p. 276 "P-Q variation and the third heart sound".)
d/ The third heart sound vibration coincides with the end of the P-wave of the following cycle. (See text p. 276 "P-Q variation and the third heart sound".)

The relation between P-Q duration and systole is portrayed also in Figure 2. Both sections of the illustration are parts of a continuous tracing taken at the aortic area. In both sections, the length of the cardiac cycles is the same. However, section A shows P-Q intervals of 0.10 sec. preceding each QRS complex, while section B shows nodal rhythm with complete superposition of the P-wave and QRS configuration. The R-peaks in both sections are arranged to lie in the same vertical plane. Prolongation of systole in the section showing auricular activity can be seen by comparing the positions of the beginning of the second heart sound in the two sections. Columns 2 to 4 of Table 2 contain the measurements of the cardiac cycles recorded in Figure 2.[5]

TABLE 2

TABLE OF MEASUREMENTS FOR FIGURE 2

(The measurements from cycles A-1, A-2 and A-3 show that, barring other physiologic changes, the duration of ventricular systole and the character of the first and second heart sounds are stable if the P-Q interval is present and does not vary significantly. The measurements from cycles B-1, B-2 and B-3 show that systole and the heart sound are also constant if the P-wave (and P-Q interval) are completely absent.)

1	2	3	4	5 b/		6
Cycle	P-Q interval (in sec.) a/	R-to-2nd sound systole (in sec.) a/	Duration of preceding diastole (in sec.) a/	Initial component of 1st heart sound	2nd component of 1st heart sound	Amplitude of downward deflection; 2nd heart sound (in mm.)
A-1	0.100	0.293	-	Absent	Taken as a basis for comparison	7.5
A-2	0.100	0.293	0.253	Absent	Similar to that of cycle A-1	7.5
A-3	0.093	0.293	0.253	Absent	Similar to that of cycle A-1	7.5
B-1	Absent	0.273	-	Absent	Amplitude and contour differ from those of cycle A-1	5.0
B-2	Absent	0.273	0.266	Absent	Similar to that of cycle B-1	5.0
B-3	Absent	0.273	0.273	Absent	Similar to that of cycle B-1	5.0

a/ See, "P-Q variation and the duration of ventricular systole."
b/ The initial component of the first heart sound can not usually be recorded on a tracing from the aortic area (see text, footnote 6).

[5] *The 'P-Q interval' and 'R-to-2nd-sound systole' columns of Table 2 show that ventricular systole is longer in cycles A-1 to A-3, where a P-Q interval is present and fairly constant, than it is in cycles B-1 to B-3, where the P-wave and P-Q interval are absent. The measurements also show that when the P-Q interval is fairly stable, as in section A, or completely absent, as in section B, the duration of ventricular systole is likewise stabilized.*

Columns 2 and 3 of Tables 3 and 4 demonstrate that the range of variation in ventricular systole due to auricular activity, lies well beyond the range due only to normal physiologic variation. The maximum difference between the longest and the shortest systolic intervals does not exceed 0.007 sec. during either sinus rhythm or nodal rhythm, for consecutive cycles of approximately the same length, provided the P-Q interval is stable or absent.

P-Q Variations and Changes in the Heart Sounds

A. P-Q Variations and the Initial Component of the First Heart Sound. The first heart sound coincides with the QRS complex, and is found directly above it on the simultaneous tracings. The exact point

TABLE 3

TABLE OF MEASUREMENTS FROM FIGURE 3

(The P-Q interval is almost completely stable in cycles 1 to 4 (cycle 4 shows a slight change of .007 sec.). The duration of ventricular systole and the first heart sound in the four cycles are constant although some change is recorded in the amplitude of the second sound. P-Q interval variations are present in cycles 5-8. The decrease in the P-Q interval is accompanied by a decrease in duration of ventricular systole and definite change in the first heart sound.)

1	2	3	4	5	6
Cycle	P-Q interval (in sec.)a/	R-to-2nd sound systole in sec.)a/	Duration of preceding diastole (in sec.)a/	Initial component of 1st heart sound	Amplitude of downward deflection; 2nd heart sound (in mm.)
1	0.133	0.326	-	Taken as a basis for comparison	1.5
2	0.133	0.326	0.306	Similar to that of cycle 1	1.0
3	0.133	0.326	0.306	Similar to that of cycle 1	1.0
4	0.140	0.326	0.332	Similar to that of cycle 1	0.5
5	0.113	0.319	0.332	Amplitude and outline differ slightly from those of cycle 1	1.0
6	0.066	0.306	0.306	Duration, outline and amplitude vary from those of preceding cycles	1.0
7	0.073	0.312	0.366	V-shaped; almost separated from body of 1st sound	0.0 + b/
8	0.073	0.312	0.352	Similar to that of cycle 7	0.0 + b/

a/ See text, "P-Q variation and ventricular systole."
b/ 0.0+ indicates less than 0.5 mm.

TABLE 4

TABLE OF MEASUREMENTS FOR FIGURE 4

	1	2	3	4	5	6
	Cycle	P-Q interval (in sec.)a/	R-to-2nd sound systole (in sec.)a/	Duration of preceding diastole (In sec.)a/	Initial component of 1st heart sound	Amplitude of downward deflection; 2nd heart sound (in mm.)
Mitral	1	0.133	0.326	-	Practically identical in the three cycles	1.0
	2	0.133	0.326	0.319		1.5
	3	0.127	0.326	0.306		1.5
Tricuspid	1	0.133	0.332	-	Practically identical in the three cycles	4.5
	2	0.133	0.326	0.293		4.5
	3	0.140	0.332	0.312		4.0
Aortic	1	0.140	0.312	-	Absent a/	3.0
	2	0.133	0.312	0.273	Absent a/	3.0
	3	0.140	0.312	0.266	Absent a/	4.0
Pulmonic	1	0.140	0.326	-	Negligible a/	2.5
	2	0.140	0.326	0.286	Negligible a/	2.5
	3	0.140	0.332	0.319	Negligible a/	2.0

a/ See text, "P-Q variation and duration of ventricular systole."
b/ The initial components of the first heart sounds, recorded on the mitral and tricuspid area tracings, end 0.5 mm. after the peak of the R-waves. The earliest vibrations of the first heart sounds recorded on the aortic and pulmonic tracings begin 0.5 mm. after the peak of the R-wave. (See also text, footnote 6.)

of coincidence depends to a great extent upon where the microphone was placed.[6] Tracings taken at the mitral area usually show a degree of clarity of detail not easily obtained at other precordial areas.

Referring therefore to the mitral area tracing of Figure 4, it is possible to distinguish four components in the record of each first heart sound. The first component consists of a short vibration of small amplitude which begins, in the four cycles shown, on the average 0.01 sec. after the initiation of the Q-wave. The first component is ended

[6] *In Figure 4 the initial vibrations of the first heart sounds, recorded at the mitral area, begin within 0.013 sec. after the onset of the Q-deflection of the electrocardiogram; whereas in the aortic area tracing, the vibrations of the first heart sound are recorded as beginning on the average 0.044 sec. after the Q-wave. At the aortic area the delayed appearance of the vibrations is probably due to the absorption and obliteration of the weak initial deflections of the first heart sound by the tissues which conduct the sounds from their points of origin to the microphone.*

rather abruptly by the second component of the first heart sound, a thin-lined, sharply pointed, single vibration, whose amplitude is greater, and wavelength less, than that of the vibration which precedes it. The second component is quite similar in frequency and amplitude to the third which follows it, and from which it is usually separated by a definite slurring, or other irregularity of the photographed galvanometer-string deflection. Following the third component, other vibrations constituting a fourth component may be distinguished. It differs from the preceding ones by being thicker in outline and having a low indefinite frequency and a smaller amplitude of vibration.

The limited variation of the different components in the first sound, when the P-Q interval is constant, is shown by the first heart sounds in Figure 3 (A), and Figure 4. (Cf. columns 2 and 5 of Tables 3 and 4.) In Figure 1, cycles 1, 2, 9, 10, and 14 may also be compared as cycles showing no auricular activity, or, as in cycle 2, only a minimal amount. (See Table 1, cf. columns 2 and 5.)

Limiting the comparison to the initial component of the first heart sound in the tracings mentioned above, it is seen that throughout any single tracing the initial components are all identical in outline and duration, and almost identical in amplitude whenever the P-Q interval is stable or absent.

A comparison of these initial components with those of the other first heart sounds recorded in Figure 1 shows that, depending on the length of the P-Q interval which precedes it, the initial component undergoes definite and characteristic changes in contour, amplitude, and duration. Some of the changes shown in Figure 1 are also listed briefly in column 5 of Table 1. The relation between the initial vibration of the first heart sound and the duration of the P-Q interval is even more clearly shown in Figure 5 (and columns 2 and 5 of Table 5). On the other hand, the lack of change in the initial component of the first heart sound is evident in Figures 3-A and 4, where the P-Q interval is seen to be quite stable.[7]

B. <u>P-Q Variations and the Second Heart Sound</u>. The second heart sound is identified on the tracing as the series of vibrations which lie above the terminal deflection of the electrocardiographic T-wave. Inspection of the second heart sounds recorded in the illustrations will show that they vary principally in amplitude according to the interval by which auricular systole preceded the ventricular contraction. The

[7]Considering the initial component of the first sound, cycle 11 of Figure 1 illustrates the fact that the length of the diastolic period preceding auricular systole is another factor which influences the character of the first heart sound. The P-Q interval of the eleventh cycle is identical with that for cycles 6 and 7. The initial component of the first sound, however, differs in all respects from those of the preceding beats. Perhaps the outstanding difference is that the initial component of the first sound in cycle 11 precedes the peak of the R-wave by 0.087 sec., while in all the other cycles, (even where the P-Q intervals are identical with that of the 11th beat) the initial vibration does not precede the R-peak by more than 0.047 sec.

By measuring the duration of the preceding diastolic period, we find that it is more than twice as long as the diastole of any other beat in Figure 1. The resulting increased filling and distension of the cardiac chamber was probably accompanied by an increased capacity for the chamber to vibrate and transmit sound vibrations. With that assumption as a basis, the early appearance and other changes in the initial vibrations of the first sound of cycle 11 may be explained as due to a greater ventricular disturbance caused by an auricular systole occurring after a prolonged diastolic filling period; as compared with the ventricular disturbance caused by auricular systole occurring after a shorter diastolic filling time, such as is seen in other cycles in Figure 1.

TABLE 5

TABLE OF MEASUREMENTS FOR FIGURE 5*

1	2	3	4	5	6
Cycle	P-Q interval (in sec.)	R-to-2nd sound systole (in sec.)	Duration of preceding diastole (in sec.)	Initial component of 1st heart sound	Amplitude of downward deflection; 2nd heart sound (in mm.)
1	0.140	0.339	-	Taken as a basis for comparison	4.5
2	0.086	0.326	0.293	Outline differs from that of cycle 1	5.0
3	0.066	0.319	0.332	Outline and ampli-tude differ from those of cycle 1	3.5
4	Absent	0.306	0.319	Outline, amplitude and duration vary from those of cycle 1	3.0
5	0.126	0.326	0.585)	Preceded by a base-line ripple but otherwise similar to that of cycle 1	4.0
6	0.133	0.332	0.273)		5.5

* See headnote to Table 1

illustrations show that the amplitude of second sounds is greatest in cycles where the P-Q intervals are longest, and least in cycles where the P-Q intervals are smallest or absent. That observation is borne out by the tables of measurements for the illustrations which give the value for the largest downward deflection of each second sound. (Cf. columns 2 and 6 of the tables.) However, it is again evident, even more so than it was with ventricular systole, that the relationship between the P-Q interval and the second heart sound in this case is a qualitative one, and can not be expressed quantitatively as in the form of a ratio.

C. P-Q Variations and the Third Heart Sound. On a stethogram the diastolic period is demarcated as the interval between the beginning of the second heart sound and that of the first sound of the succeeding cycle (1). During diastole, a third heart sound may be detected in some individuals. When present, it usually occurs from 0.11 sec. to 0.14 sec. after the second sound (4). The third heart sound is caused by the inrush of blood to the ventricles during the period of rapid ventricular filling which takes place when the auriculo-ventricular valves open, early in diastole (6, pp. 409-410).

Since the force of impact and the turbulence created by the rush of blood into the ventricles depend largely on the pressure difference between auricles and ventricles at the moment the A-V valves open, varia-

tions of venous pressure under different conditions may cause the third heart sound to appear only intermittently in the same individual. For example, a third heart sound can be detected in the mitral area tracing of Figure 1, 0.15 sec. after the second sound, but can not be demonstrated in the mitral tracings of the other illustrations. Even in Figure 1, the intensity of the third sound vibrations is seen to vary from cycle to cycle. In the cycles where a P-wave appears simultaneously with the third heart sound, or precedes it by only a small interval, the third sound is recorded at its maximum amplitude; but in cycles where the P-wave is absent, or follows the third sound, the sound is minimal.

Figure 1, then, suggests that an auricular systole during the period of rapid ventricular filling accentuates the third heart sound, probably by augmenting the pressure difference between the auricles and the ventricles. In cycles 1, 2, 8, 9, 10, 11, and 13, P-waves either do not occur, or occur after the third heart sound, and the intensity of the sound is minimal (with few exceptions). The converse is evident in cycles 3, 4, 5, 6, 7, and 12, where the P-waves occur simultaneously with, or slightly ahead of, the third sound.

Discussion

In the case discussed in the preceding report, the presence or absence of an auricular contraction before ventricular systole, and variations in the As-Vs interval played an important part in varying the characteristics of the first, second, and third heart sound and the duration of ventricular systole. The constancy of the indicated relationships during any one day and over extended periods of time suggests that the relations reported for this instance might profitably be investigated in other such cases.

It has previously been observed that auricular activity may influence the character of the first, second, and third heart sounds. Cutts mentions variations of the first and second heart sounds detected on auscultation in many of the cases described in his report on nodal rhythm and A-V dissociation (2). Levine refers to the fact that the loudness of the first heart sound is directly related to the P-R interval (3). The possibility of an auricular systole preceding, or coinciding with a third heart sound and thereby augmenting its intensity has also been reported (5). However, the literature searched does not reveal any other investigation of the relation between the duration of ventricular systole and the time elapsing between auricular and ventricular contractions.

SUMMARY

There is presented a stethographic study of a clinically normal case, in whom spontaneous transitions between normal sinus rhythm, A-V dissociation, and nodal rhythm were detected.

In the above mentioned case, also reported in the preceding communication of this series, stethography demonstrates that:

1. Ventricular systole is invariably longer in cycles initiated by auricular activity than in comparable cycles in which there is not a complete auricular contraction preceding ventricular systole.

2. The acoustic characteristics of the first heart sound, and, to a lesser extent, of the second, vary according to the time interval between auricular and ventricular contractions.
3. The third heart sound, when present, is strengthened in intensity if it occurs simultaneously with, or slightly after, an auricular contraction.

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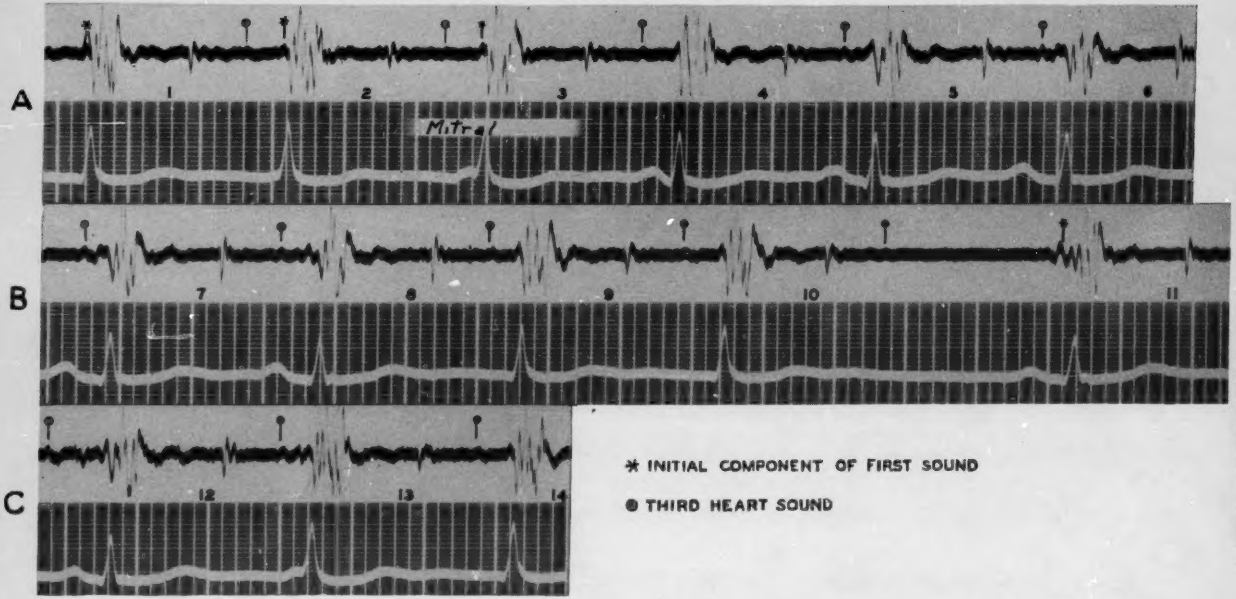

Figure 1. Mitral-area stethogram recorded simultaneously with Lead II, in sitting position. The tracing is continuous. Section A shows a transition from nodal to sinus beats; section B, an abrupt return to a sinus beat after a prolonged diastole due to nodal arrest; and section C, transition from sinus to nodal rhythm. (See text, and Table 1.)

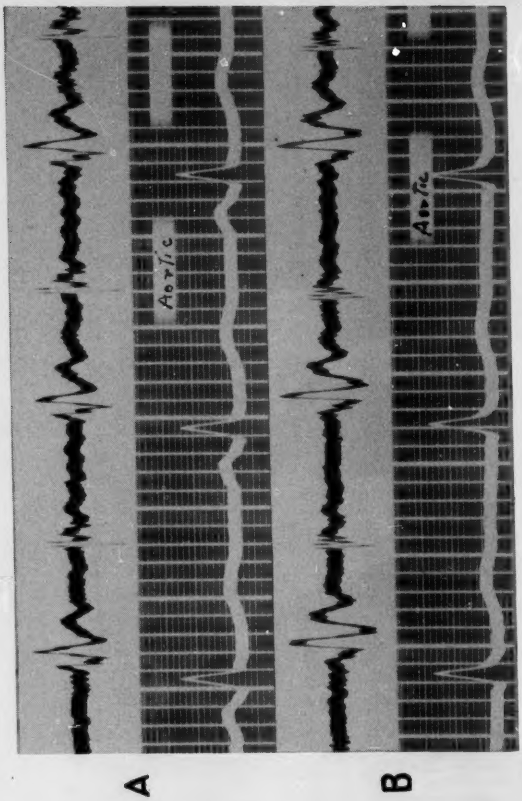

Figure 2. Portions of an aortic-area stethogram taken simultaneously with Lead II. Section A shows auricular activity preceding ventricular systole; section B shows superposition of P-and QRS-configurations. The cycle lengths in both sections are the same, and the QRS complexes lie in the same vertical planes. Note, however, that the beginning of the second heart sound in section B precedes that in section A, and the amplitude of the second sound in B is smaller than it is in A. (See text, and Table 2.)

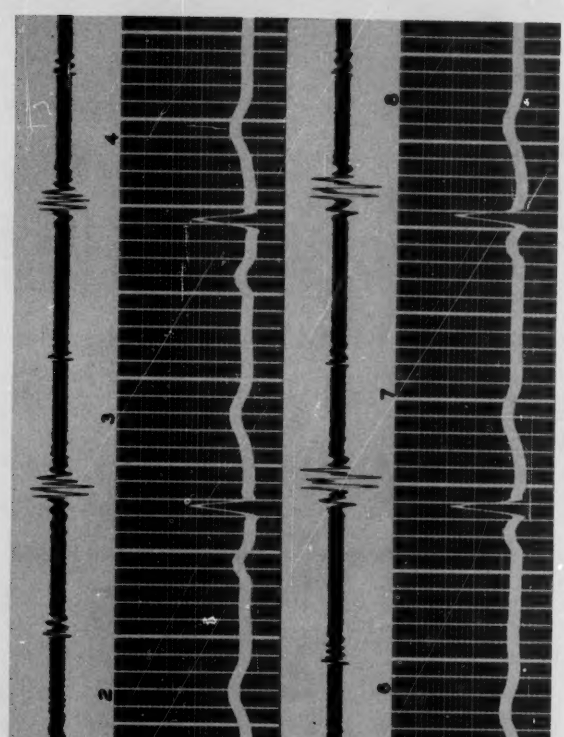

Figure 3. Mitral-area stethogram and simultaneous ECG, Lead II, taken in lying position. The tracing is continuous. A transition from sinus rhythm to A-V nodal escape begins with cycle 5. (See text, and Table 3.)

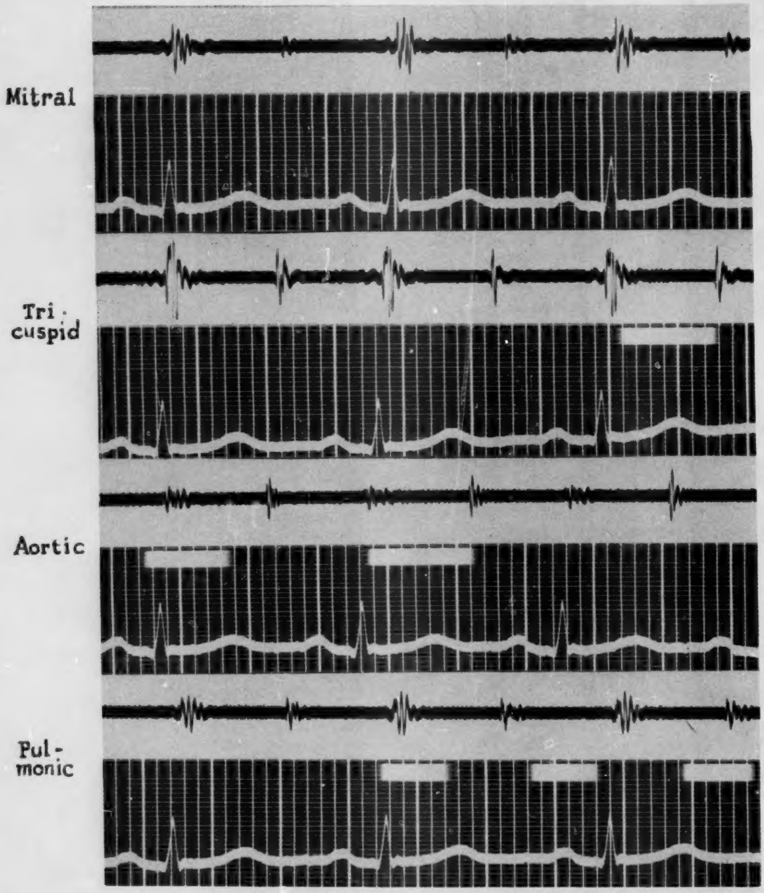

Figure 4. Stethograms taken simultaneously with Lead II, in the lying position. A. mitral-area tracing; B. tricuspid-area tracing: C. aortic-area tracing: D. pulmonic-area tracing. Sinus rhythm is present throughout. With minor exceptions, the heart sounds and duration of ventricular systole show no variation. (See text and Table 4, and compare with other illustrations.)

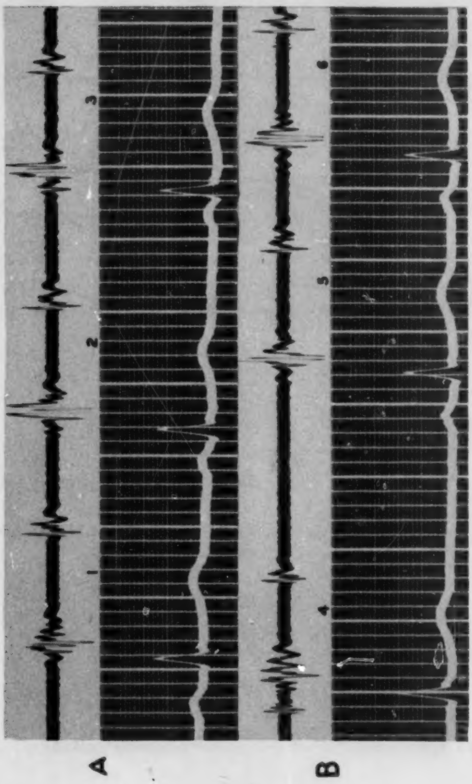

Figure 5. Tricuspid-area tracing taken simultaneously with Lead II, in the lying position. The tracing is continuous. Changes due to P-Q variations can be seen in the configuration of the first, and the amplitude of the second, heart sounds. Table 5 shows the changes in systolic length. (The vibrations preceding the first sound of cycle 4 are an artifact.)

Contents for December

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